Hazard Profile – Avalanche

Summary

- The hazard – An avalanche occurs when a layer of snow loses its grip on a slope and slides downhill. Avalanches typically occur from November until early summer in all mountain areas, but year-round in high alpine areas. They primarily pose danger to people in areas where there is no avalanche control, and to continued movement of people and freight over the state's mountain highway passes.

- Previous occurrences – Avalanches occur frequently each year and kill one to two people annually in the Northwest (about 25-35 deaths annually in the U.S.). Avalanches have killed more people in Washington than any other hazard during the past century. In 90 percent of avalanche fatalities, the weight of the victim or someone in the victim's party triggers the slide.

- Probability of future events – Avalanches occur regularly every year in mountain areas. Many weather and terrain factors determine actual avalanche danger. Avalanches along two key mountain highway passes are limited due to ongoing mitigation to control slides during winter months.

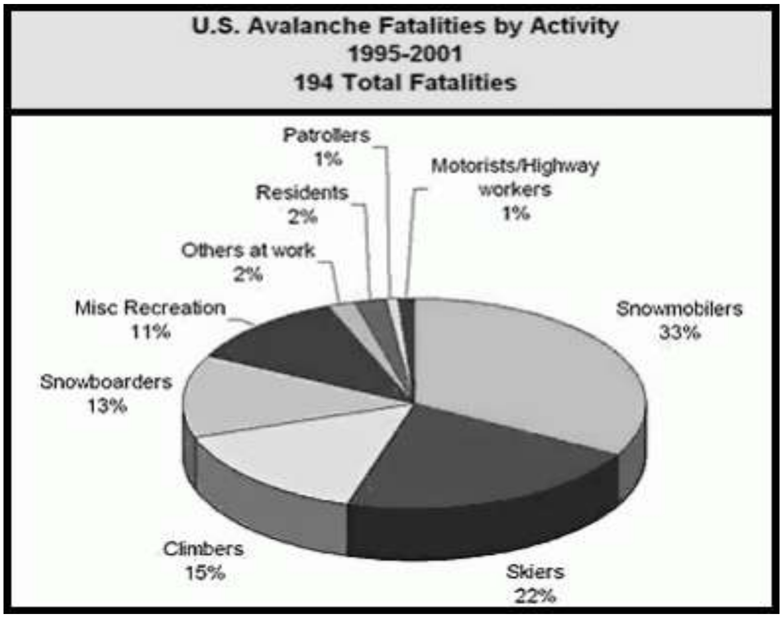
- Jurisdictions at greatest risk – Twelve counties in which the Cascade, Olympic, Blue or Selkirk Mountains are found.

- Special note – This profile will not attempt to estimate potential losses to state facilities due to avalanche. Very few are in avalanche hazard zones, and other hazards pose a greater threat to people and the built environment than avalanches and are more important to address. However, this hazard profile will identify a number of state highways that experience closure due to avalanches during the winter months.

Introduction[1, 2, 3, 4, 5]

An avalanche occurs when a layer of snow loses its grip on a slope and slides downhill. Avalanches have killed more than 190 people in the past century in Washington State, exceeding deaths from any other natural hazard. The nation's worst avalanche disasters occurred in 1910 when massive avalanches hit two trains stopped on the west side of Stevens Pass; at least 96 people were killed. Avalanches kill one to two people, on average, every year in Washington, although many more are involved in avalanche accidents that do not result in fatalities. Since 1985, avalanches have killed 53 people in Washington State (through January of 2010).

Most current avalanche victims are participating in recreational activities in the backcountry where there is no avalanche control. Only one-tenth of one percent of avalanche fatalities occurs on open runs at ski areas or on highways.



Source: USDA Forest Service Utah Avalanche Center. (Accessed Aug. 10, 2009)
Available at: http://utahavalanchecenter.org/education/faq

Avalanches occur in four mountain ranges in the state – the Cascade Range, which divides the state east and west, the Olympic Mountains in northwest Washington, the Blue Mountains in southeast Washington, and the Selkirk Mountains in northeast Washington.

The avalanche season begins in November and continues until early summer for all mountain areas of the state. In the high alpine areas of the Cascades and Olympics, the avalanche season continues year-round.

There are two types of avalanches, loose and slab, and two types of slab avalanches, dry and wet. Although the most dangerous avalanche is the slab avalanche, loose slides can and do produce injury and death.

Loose avalanches occur when grains of snow cannot hold onto a slope and begin sliding downhill, picking up more snow and fanning out in an inverted V. Slab avalanches occur when a cohesive mass of snow breaks away from the slope all at once. Most slides in the Northwest are slab avalanches.

Avalanches occur for one of two basic reasons:

1) Either the load on a slope increases faster than snow strength; or
2) Snow strength decreases.

Dry slab avalanches occur when the stresses on a slab overcome the slabs attachment strength to the snow layer below. A decrease in strength produced through warming, melting snow, or rain. An increase in stress is produced by the weight of additional snowfall, or a skier or a snowmobile. Dry slab avalanches can travel 60 to 80 miles per hour or more, reaching these speeds within five seconds after the fracture; they account for most avalanche fatalities. Wet slab avalanches occur when warming temperatures or rain increase the creep rate of the surface snow, putting additional forces on the slab's attachment to the layer below. When water percolating through the top slab weakens the layer and dissolves its bond with a lower layer, it decreases the ability of the weaker, lower layer to hold on to the top slab, as well as decreases the slab's strength.

In 90 percent of avalanche fatalities, the weight of the victim or someone in the victim's party triggers the slide. An avalanche is like a dinner plate sliding off a table; a slab of snow shatters like a pane of glass with the victim in the middle.

Factors That Affect Avalanche Danger[6]

A number of weather and terrain factors determine avalanche danger:

Weather:

- Storms – A large percentage of all snow avalanches occur during and shortly after storms.
- Rate of snowfall – Snow falling at a rate of one inch or more per hour rapidly increases avalanche danger.
- Temperature – Storms starting with low temperatures and dry snow, followed by rising temperatures and wetter snow, are more likely to cause avalanches than storms that start warm and then cool with snowfall.
- Wet snow – Rainstorms or spring weather with warm, moist winds and cloudy nights can warm the snow cover resulting in wet snow avalanches. Wet snow avalanches are more likely on sun-exposed terrain (south-facing slopes) and under exposed rocks or cliffs.
- Wind is the most common cause of avalanches. Wind can deposit snow 10 times faster than snow falling from storms. Wind erodes snow from the upwind side of obstacles and deposits snow on the downwind (lee) side. This is called "wind loading".

Terrain:

- Ground cover – Large rocks, trees and heavy shrubs help anchor snow, but also create stress concentrations between anchored and unanchored snow.
- Slope profile – Dangerous slab avalanches are more likely to occur on convex slopes that produce stress concentrations within surface snow due to varying creep rates.
- Slope aspect – Leeward slopes are dangerous because windblown snow adds depth and creates dense slabs. South facing slopes are more dangerous in the springtime due to increasing solar effects.
- Slope steepness – Snow avalanches are most common on slopes of 30 to 45 degrees.

Avalanche forecasting and control is a regular winter expense. The Washington State Department of Transportation's annual budget for removing snow and ice and for avalanche control for the highways that cross the Cascade Mountains is about $38 million. Additionally, the transportation department, ski areas, State Parks and Recreation Commission, US Forest Service, National Weather Service, National Park Service, and other agencies, help fund the Northwest Weather and Avalanche Center, which provides daily forecasts throughout the avalanche season for those involved with highway avalanche control and for recreationalists. In FY 2008, the avalanche center received approximately $527,211 in direct funding and in-kind contributions for its operations.[7]

During the avalanche season, the Northwest Weather and Avalanche Center issues daily forecasts as well as special statements and avalanche warnings during times of significantly increased avalanche danger. Additionally, the NWAC maintains and manages a comprehensive network of remote mountain weather stations (see www.nwac.us/weatherdata/map/) that provide hourly weather data to users and cooperators alike.

The informational chart below details the current 2009/10 version of the US danger scale utilized by the NWAC when issuing their warnings (note that new definitions for the 5-level North American danger scale have been recently adopted and will be used in 2010/2011).

US AVALANCHE DANGER SCALE (1997)

Danger Level and Color	Avalanche Probability and Avalanche Trigger	Degree and Distribution of Avalanche Danger	Recommended Actions in the Backcountry
What…	Why…	Where…	What to do…
LOW (Green)	Natural avalanches very unlikely. Human triggered avalanches unlikely.	Generally stable snow. Isolated areas of instability.	Travel is generally safe. Normal caution is advised.
MODERATE (Yellow)	Natural avalanches unlikely. Human triggered avalanches possible.	Unstable slabs possible on steep terrain.	Use caution in steeper terrain on certain aspects.
CONSIDERABLE (Orange)	Natural avalanches possible. Human triggered avalanches probable.	Unstable slabs probable on steep terrain.	Be increasingly cautious on steeper terrain.
HIGH (Red)	Natural and human triggered avalanches likely.	Unstable slabs likely on a variety of aspects and slope angles.	Travel in avalanche terrain is not recommended. Safest travel on windward ridges of lower angle slopes without steep terrain above.
EXTREME (Red with Black Border)	Widespread natural and human triggered avalanches certain.	Extremely unstable slabs certain on most aspects and slope angles. Large destructive avalanches possible.	Travel in avalanche terrain should be avoided and travel confined to low-angle terrain well away from avalanche path run-outs.

US Danger Scale (1997). Accessed Aug. 10, 2009. Available at: http://www.nwac.us/education/avydangerscale/

Avalanche Mitigation[8]

The Washington Department of Transportation conducts active winter time avalanche control or mitigation on two of the state's mountain highway passes, Stevens Pass on

U.S. Route 2, and Snoqualmie Pass on Interstate 90. This means avalanches are triggered intentionally on slopes above the roadways in a controlled environment to minimize traffic disruption and promote public safety. It also conducts passive avalanche control through elevated roadways so avalanches can pass under highways, snow sheds built avalanching snow flows over highways, catchment basins to stop avalanche flow, and diversion dams and berms to keep snow off highways.

Avalanche control is important along Stevens Pass and Snoqualmie Pass. These highways are heavily traveled corridors which connect major Puget Sound communities to Eastern Washington through the Cascade Mountains. Snoqualmie Pass is the state's only Interstate highway link through the Cascades. It averages nearly 450 inches of snow each winter and has a daily traffic volume of 32,000 vehicles (including 8,000 trucks). A two-hour closure of the pass costs the state's economy more than $1 million.

Intermittent winter time avalanche control is also used by WSDOT along US-12 (White Pass) when conditions warrant; avalanche control is also done during spring time re-opening of SR 410 (Chinook and Cayuse Passes) and SR 20 (Washington Pass).

Selected Avalanches in Washington State – 1910 to Present[9]

Date	Location	Casualties
1910	Stevens Pass	Two trains swept off their tracks, 96 dead.
1939	Mount Baker	6 dead
1958	Silver Creek	4 buried
1962	Granite Mountain	2 dead
1962	Stevens Pass	2 buried
1971	Yodelin	4 dead, several buried
1974	Source Lake	2 dead
1975	Mount St. Helens	5 dead
1981	Mount Rainier	19 dead, 18 injured
1988	Mount Rainier	3 dead
1992	Mount Rainier	2 dead
1994	Mission Ridge	1 dead
1996	Index	3 dead
1996-97	Snoqualmie Pass	Hundreds of travelers stranded after repeated avalanches closed Interstate 90 during the holidays.
1998	Drop Creek	Snowmobile buried, 1 dead
1998	Mount Rainier	1 climber dead, several climbers injured.

Date	Location	Casualties
1998	Mount Baker	1 dead
1999	Mount Baker	1 snow boarder and 1 skier dead
2000	Crystal Mountain	1 dead
2001	Twin Lakes	2 dead
2001	Mount Baker	1 dead
2001	Lake Ann	1 dead
2002	Crystal Mountain	1 dead
2003	Snoqualmie Pass	1 snowshoer dead
2003	Mount Baker	1 snowshoer dead, 2 snowshoers injured
2003	Navajo Peak	1 snowmobiler dead
2004	Mount Baker	1 snowboarder dead
2004	Mount Rainier	2 climbers dead
2005	Snoqualmie Pass	1 skier dead
2005	Mount Baker	2 snowboarders buried – found alive by beacon (2 separate incidents/days)
2006	Mount Baker	1 skier dead
2006	Tiffany Mountain	1 snowmobiler dead
2006	Mount Hood	3 skiers buried
2007	Edit Ck Basin, Mt Rainier National Park, WA	2 snowshoers totally buried, found by probing under ~6-10 ft of snow.
2007	Union Creek, south-central WA Cascades, northeast of Crystal Mt, WA	3 snowboarders dead. Group departed on weekend trip on 11/30/2007. Reported missing on 12/2/07. Subsequent searches on ground and air found no evidence of any of the group. Official search abandoned 12/8/07. Final Search and Recovery effort concluded late June, 2008 when the three missing snowboarders were found buried in avalanche debris in Union Creek.
2007	Northway at Crystal Mt Resort, WA	Two ski patrollers caught, 1 totally buried, 1 mostly buried and able to self extricate--found and rescued partner; south-central Washington Cascades at Crystal Mountain Resort, WA
2007	Snoqualmie Pass	2 hikers killed; 1 additional buried, injured & self rescued,
2007	Mount Rainier	1 skier dead
2008	Rockford, WA	1 resident caught, buried and killed by roof avalanche while shoveling walk and clearing roof
2008	Tatie Peak, near Harts Pass, northern WA Cascades	1 snowmobiler dead

Date	Location	Casualties
2008	Kahler Glen, north-central WA Cascades near Lake Wenatchee	A large natural avalanche released during the late afternoon of February 7, impacting and mostly destroying a home in the Kahler Glen development just above and west of the Kahler Glen Golf Course
2008	Lake Twenty-two trail near Mt. Pilchuck, north-central WA Cascades	8 hikers descending Lake Twenty-Two Trail; 4 in party were caught by avalanche. Slide partially buried one; totally buried three. Three were found by spot probing and survived; 1 not recovered until later by rescue team died.
2008	Excelsior Pass below Church Mt,, northern WA Cascades	5 snowmobilers high marking in the Excelsior Pass area triggered a large 5-7 ft deep slab. The avalanche caught five, partly burying one, totally burying and killing two. Victims reportedly found by beacon and probing under three and six feet of snow.
2009	Aneroid Basin, Wallowa Mountains, NE Oregon	Three skiers caught, two totally buried and one partially buried. One skier recovered alive after ~10 minutes, one found dead after ~30 minutes
2009	Hogsback Mtn, south-central WA Cascades	One skier caught and completely buried under ~2.5 ft of snow. Found by partner's beacon and recovered within about 10 minutes.

Jurisdictions Most Vulnerable to Avalanches

Based on the location of key transportation routes and recreational areas threatened by avalanche, parts of the following counties are most vulnerable to avalanche (see map, page 9):

Asotin	Chelan	Ferry	Garfield
King	Kittitas	Klickitat	Lewis
Okanogan	Pend Oreille	Pierce	Skagit
Skamania	Snohomish	Whatcom	Yakima

Transportation routes threatened by avalanche[10, 11, 12]

Highway closures due to avalanche can have a significant economic impact on the state. Economists estimate that closing Interstate 90 over Snoqualmie Pass has an economic cost to the state of between $500-750,000 per hour for stalled shipping, lost perishables, and rerouting. During the winter of 1996-97, there were 276 hours of closure of I-90 over Snoqualmie Pass, 70 percent related to avalanche control and avalanche safety closures; these closures were more than in any other year in recent times. The closures cost the state's economy an estimated $144 million (in 2002 dollars).

The Washington Department of Transportation spends considerable effort each winter keeping the following mountain passes open and free from avalanches:

- King County – Snoqualmie Pass I-90, Stevens Pass US 2.
- Kittitas County – Snoqualmie Pass I-90, Blewett Pass US 97.
- Chelan County – Stevens Pass and Tumwater Canyon US 2.

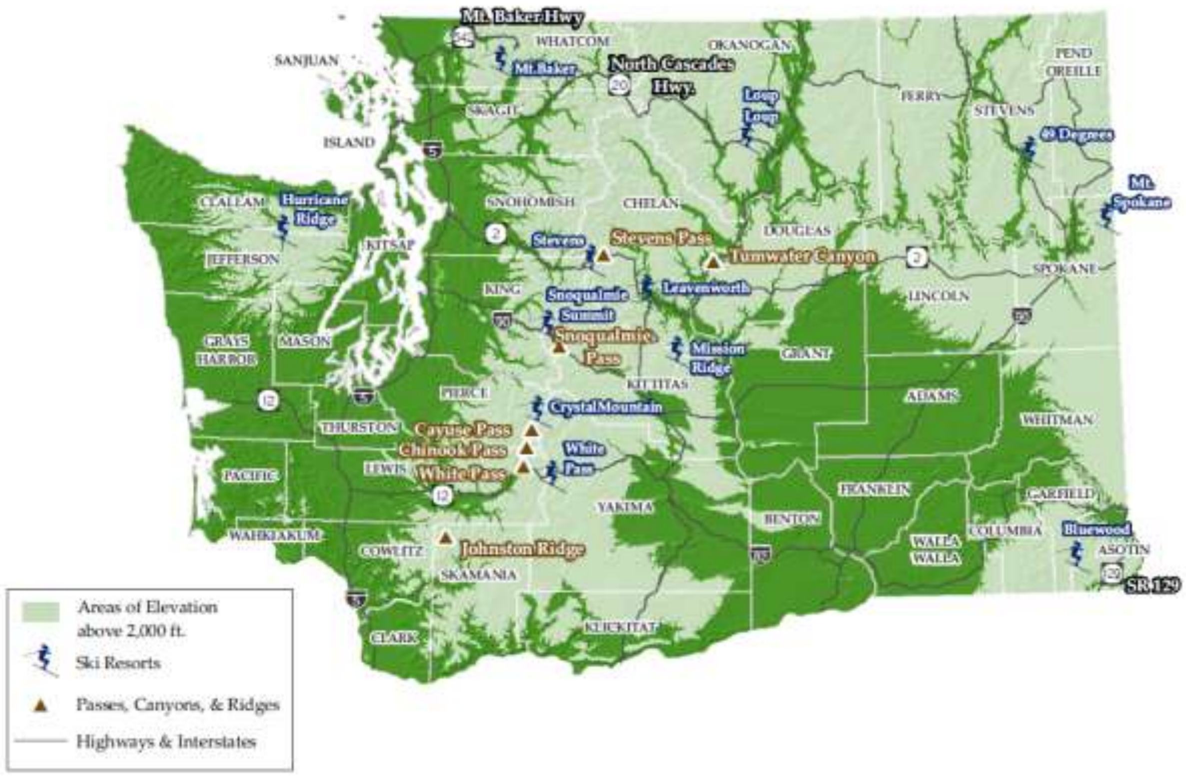
Passes closed all winter with spring openings that have residual avalanche hazard after they are open are:

- Pierce – Chinook Pass SR 410, Cayuse Pass SR 123.
- Skagit – North Cascades Highway SR 20.

Mountain passes and highways that pose avalanche problems or that have the potential for problems in the worst conditions are:

- Lewis and Yakima Counties – White Pass US 12.
- Skagit – Diablo Canyon SR 20.
- Skamania – Johnston Ridge, SR 504.
- Asotin County – SR 129 south of Anatone.
- Whatcom County – SR 542 to the Mount Baker Ski Area.

Areas Vulnerable to Avalanche



For general location of these transportation routes, see map below.

Recreation areas threatened by avalanche[13]

With better equipment allowing more people to explore further into the wilderness, areas threatened by avalanche are those accessible by skiers, snowshoers, snowboarders, climbers, and snowmobilers outside developed ski resorts in the mountains of Washington. This includes the areas that people can reach via Sno-Parks (parking lots cleared of snow) in Asotin, Chelan, Ferry, Garfield, King, Kittitas, Klickitat, Lewis, Okanogan, Pend Oreille, Pierce, Skagit, Skamania, Snohomish, Whatcom, and Yakima counties; Hurricane Ride in Olympic National Park (Clallam County) is another area providing easy access to avalanche-prone terrain (see map generally depicting areas at-risk to avalanche below).

Hazard Profile – Avalanche

State Agency Structures At Risk

Number and Function of Buildings	No. of Affected Staff / Visitors / Residents	Approx. Value of Owned Structures	Approx. Value of Contents
Total at-risk buildings: 0	0	0	0

However, State Department of Transportation has identified a number of state highways as being at risk to avalanche:

1. Asotin County – SR 129 south of Anatone.
2. Chelan County – Stevens Pass and Tumwater Canyon US 2.
3. King County – Snoqualmie Pass I-90, Stevens Pass US 2.
4. Kittitas County – Snoqualmie Pass I-90, Blewett Pass US 97.
5. Lewis and Yakima Counties – White Pass US 12.
6. Pierce – Chinook Pass SR 410, Cayuse Pass SR 123.
7. Skagit – North Cascades Highway SR 20.
8. Skamania – Johnston Ridge, SR 504.
9. Whatcom County – SR 542 to the Mount Baker Ski Area.

Total at-risk critical facilities: 0	0	0	0

Four state highways considered emphasis corridors because of their importance to movement of people and freight have been identified as being at risk to avalanche:

1. U.S. Highway 2
2. U.S. Highway 12
3. Interstate 90.
4. U.S. Highway 97

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[1] *Washington State 2001 Hazard Identification and Vulnerability Assessment*, Washington State Military Department, Emergency Management Division, April 2001.

[2] Bruce Tremper. *Frequently Asked Questions about Avalanches*, USDA Forest Service Utah Avalanche Center. (Undated) Accessed: Aug. 10, 2009. Available at: http://utahavalanchecenter.org/education/faq.

[3] *United States Avalanche Fatalities by State, 1985-86 to 2009/10(Feb 1, 2010)*, Northwest Weather and Avalanche Center, http://www.nwac.us/media/uploads/pdfs/US%20Annual%20Avalanche%20Statistics%20by%20State--1985-20XX.pdf (Feb 1, 2010).

[4] Written communication from avalanche forecaster Mark Moore, Northwest Weather and Avalanche Center, U.S. Department of Agriculture, May 9, 2003

[5] Ron Judd, *Northwest mountains have the right ingredients for avalanches*, Seattle Times, February 22, 2004.

[6] *Avalanche Danger*, Mount Rainier National Park, online fact sheet, http://www.nps.gov/mora/planyourvisit/upload/avalanche.pdf, (Undated).

[7] *Northwest Weather and Avalanche Center 2007-2008 Annual Report*, United States Department of Agriculture, U.S. Forest Service Pacific Northwest Region, May 2008.

[8] *Avalanche Control*, Washington State Department of Transportation fact sheet, http://www.wsdot.gov/maintenance/avalanche/, (January 31, 2006)

[9] Northwest Weather and Avalanche Center. Recent Northwest Avalanche Accident Summaries, 1998-2009. Accessed Feb. 19, 2009. Available at: http://www.nwac.us/accidents/

[10] Written communication from Terry Simmonds, Washington State Department of Transportation, March 27, 2003.

[11] Tom Paulson, *In Avalanche County, Thinnest of Defenses Hangs Tough*, Seattle Post-Intelligencer, December 27, 2001.

[12] Written communication from Terry Simmonds, Washington State Department of Transportation, March 27, 2003.

[13] Oral communication with avalanche forecaster Mark Moore, Northwest Weather and Avalanche Center, U.S. Department of Agriculture, April 8, 2003.